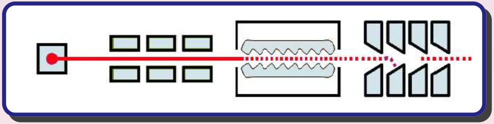
The RAL Front-End Test Stand (FETS)

Frank Gerigk for the FETS study team

CCLRC, ASTeC, Intense Beams Group

Joint DL/RAL meeting, 28.02.05, DL



The FETS Collaboration

Participating Institutes

FETS

Front **E**nd **T**est **S**tand

CCLRC/RAL/ISIS

MA Clarke-Gayther (chopper)
DC Faircloth (ion source)
DJS Findlay (head ISIS)
AP Letchford (head FETS)
EJ McCarron (engineering)

Imperial College/HEP

GR Gosling (mech. eng.)
A Kurup (RF simulations)
KR Long
J Pozimski (diagn., LEBT)
P Savage (design engineer)

CCLRC/RAL/ASTeC

G Bellodi (beam dynamics)
F Gerigk (beam dyn., RF)

Warwick/Physics Dept.

JJ Back (LEBT)
PF Harrison

Motivation to build a high-power H^- **F**ront-**E**nd **T**est **S**tand

- high power proton linacs injecting into subsequent ring systems need low-energy beam chopping for low-loss injection,
- these linacs are the basis for future spallation neutron sources and neutrino factory proton drivers,
- so far low-energy (2.5 - 3 MeV) beam chopping at high duty cycles ($\approx$ 1-10%) has not been demonstrated (!), 2 systems have been tested at low dc (SNS, JPARC),
- the RAL FETS is the first stage for a new 180 MeV linac for upgrades of ISIS (0.5 MW and beyond) and provides R&D opportunities for future high-power linacs.

Low Loss Injection

- Longitudinal focussing of bunches in the ring (and the linac) is provided by the RF system.
- Particles within the stable area (the "RF bucket") can be "lifted" to higher energy or can be focused.

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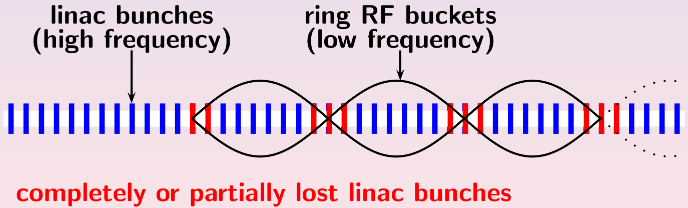

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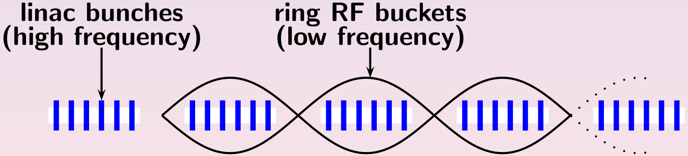
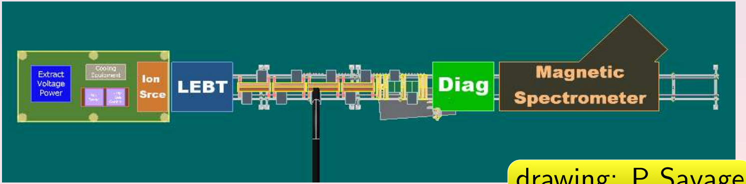


A low energy beam chopper is needed to remove selected bunches from the linac beam.

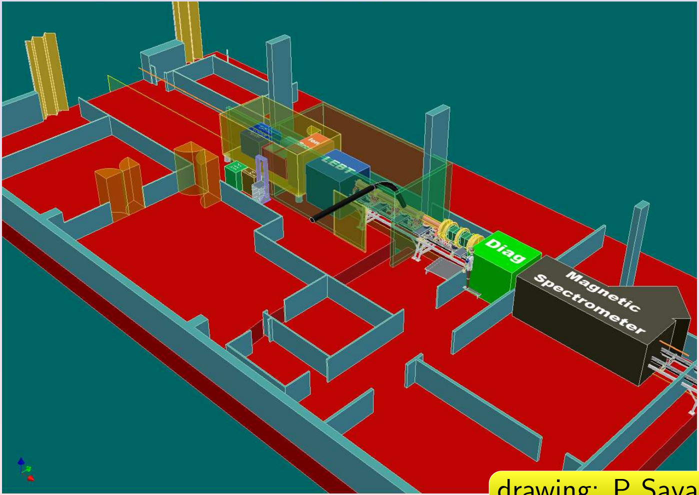
General Layout

- Ion source,
- Low Energy Beam Transport (LEBT),
- Radio Frequency Quadrupole (RFQ),
- Medium Energy Beam Transport (MEBT) with beam chopper,
- diagnostics.



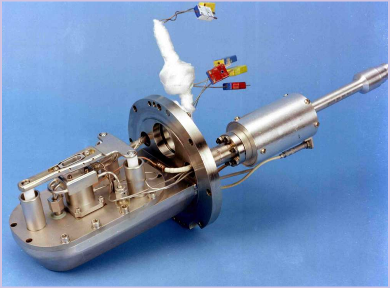
drawing: P Savage

Location: RAL/R8



drawing: P Savage

RAL H^- Source (DC Faircloth)



Present Performance in ISIS:

- Penning surface plasma type,
- 30 mA, 200 μs pulse length, 50 Hz,
- up to 50 days continuous operation.

Progress & Goals

➜ achieved last week: 60 mA, reduced output emittance, $\approx$ xxx μs pulse length,

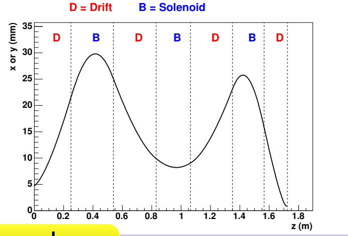
- goals: reduce output emittance, up to 2 ms pulse length, higher current,
- means: extensive thermodynamic and electrodynamic 3D modelling including particle tracking, further prototypes are constructed and tested now.

LEBT (JJ Back)

- two possible solutions: electrostatic (SNS) or with solenoids (ISIS, SPL, JPARC),
- at SNS sparking problems due to caesium spillage from the source,

→ for the FETS a 2-solenoid LEBT looks most attractive.

- modelling of KV envelope equations with ENVELPC (IAP Frankfurt),
- numerical optimisation of elements for the desired output parameters.

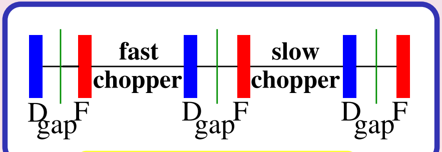


x-envelopes

ESS chopper scheme

- fast chopper removes 3 bunches, during that time the slow chopper rises to its max. voltage and chops for 240 ns-0.1 ms,
- chopped beam is collected on the plates of the slow chopper,
- to minimise heat load 2 units of fast/slow choppers were employed.

	fast	**slow**
voltage	$\pm$ 2.2 kV	$\pm$ 6 kV
deflection angle	16 mrad	66 mrad
pulse width	12 ms	240 ns - 0.1 ms



basic unit of ESS chopper

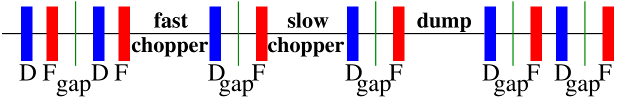
FETS-scheme

- chopped beam from the slow chopper is collected in subsequent period in a dedicated dump $\rightarrow \approx 30\,\%$ of original plate voltage required ($6\,\mathrm{kV} \rightarrow 1.7\,\mathrm{kV}$),

$\rightarrow$ faster rise time for slow chopper, now fast chopper only needs to chop 2 bunches,

$\rightarrow$ smaller bandwidth required for fast chopper which should improve performance of fast chopper pulser (droop, rise time),

- dedicated beam dump can be designed to take full beam power $\rightarrow$ no need for 2 identical chopper sections.

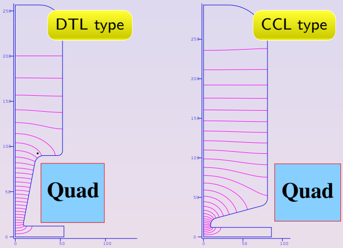


chopper line for FETS

Buncher cavities

two types of buncher cavities are considered:

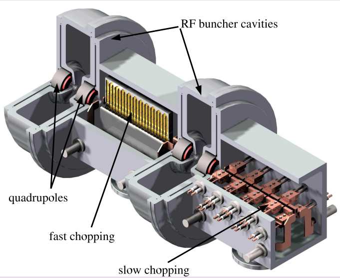
- DTL type: compact, high power consumption,
- CCL type: larger, low power consumption.



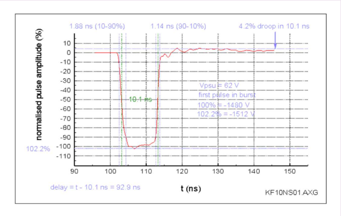
	DTL type	CCL type	
frequency	324	324	MHz
E_0TI	100/150	100/150	kV
P^*_{peak}	14.9/33.6	4.2/9.5	kW
Q	18900	28200	
r/Q	21.3	50.6	Ω
$P_{peak,surface}$	4.8/10.8	2.3/5.2	W/cm^2
gap length	18	18	mm
bore radius	12	12	mm
Kilpatrick	0.7/1.0	0.7/1.0	

Fast Beam Chopper (M Clarke-Gayther)

Chopper Line Segment



Amplifier pulse shape

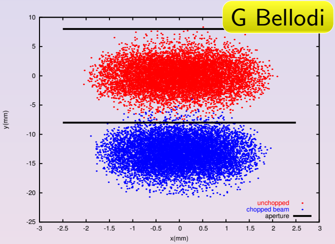


- essential for low-loss injection into subsequent ring systems,
- alternative approach to SNS/CERN,
- two stage chopping: fast rise-time (short duration) field removes 2 microbunches to create space for a slower rise-time (long duration) field to remove 50 microbunches.

First tracking results

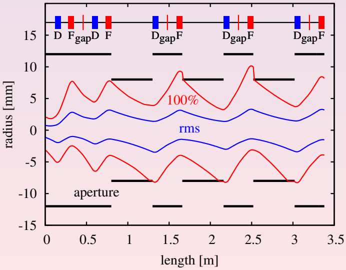
Beam separation at the dump:

- 3D tracking with PATH (LANL/CERN),
- ➜ clean beam separation can be achieved.



Nominal beam tracking

- 3D tracking with IMPACT using realistic RFQ output distribution,
- ≈1 % beam loss for nominal beam,
- $<$ 10 % rms emittance growth.



Diagnostics

LEBT space charge compensation with electrostatic spectrometer of Hugh-Rojanski type (J Pozimski in collaboration with IAP, GSI, CEA),

ε measurements with emittance scanners from the RAL RFQ test stand,

laser based systems under discussion (system of IAP Frankfurt could be adapted),

energy & energy spread with gas scattering energy analyser from RAL RFQ test stand,

halo need for high resolution measurements $\approx 10^{-5}$ to quantify halo content of the beam (CERN system could be adapted).

Conclusions & outlook

- a viable base-line design for the FETS is established and verified by 3D particle tracking,
- basic design is derived from the ESS, but offers: simpler mechanical design, improved performance, reduced cost,
- technology exists for: H^- source, LEBT, chopper plates & amplifier, beam emittance & energy diagnostics,
- design work needs to done for RFQ, buncher cavities, magnets, dump, additional diagnostics, low-level RF,
- contact with Toshiba on 324 MHz klystrons.

visit: http://fets.isis.rl.ac.uk